# THERMODYNAMICS: AN IDEOLOGY OR AN APPROXIMATION?

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Received September 24, 1987

ABSTRACT

Thermodynamics is taken as an instance in the analysis of the interplay between empirical observations and theoretical propositions. A methodological example is given, in which it is shown that the ideology implicit in the language of thermodynamics is apt to give a universal description of both thermodynamic as well mechanical behaviour.

RESUMO

A relação entre observação empírica e proposição teórica é discutida através de uma análise da estrutura da Termodinâmica. Discute-se um exemplo metodológico para mostrar que a ideologia implícita da Termodinâmica é capaz de servir como base de uma descrição universal dos comportamentos tanto termodinâmico como mecânico.

## 1. INTRODUCTION

Science rests on a fundamental tripod: phenomenon, ideology and language. The relations among the elements of this triad is complex and imbricated, not one of them being independent of the other two. Men have to refer to phenomena, and this can be done only from a stand point, i.e. we formulate linguistic propositions relative to what we observe, but the language itself depends on the point of view of the observer, the ideology which, by its turn, can be expressed only by means of a language. Thus, all we can argue about this triad is in relation with the requirement of coherence, non-contradiction.

Since Napoleon, short after the French Revolution, the term "ideology" has become a matter of emotional controversy. In this paper we use the term in a sense accepted by most contemporary dictionaries: "a manner or the content of thinking characteristic of an individual, group, or culture"[1].

Thermodynamics deals with two interrelated facts, viz. that many physical objects are known which (i) when left by themselves, they, slowly or rapidly, tend towards a final state of equilibrium, and (ii) this tendency is steadily unilateral, in the sense that no over-shoot occurs, that is, the object never comes back to any previously observed state. In this paper we discuss the non-empirical content of the propositions of Physics, and speculate on various ideological possibilities for the foundation of Physics.

## 2. THE SECOND LAW OF THERMODYNAMICS

Many systems approach the equilibrium state at a rate which leaves no doubt that the more we wait, all the rates of change become smaller and smaller, so that we find no reason to doubt that the final state of equilibrium is closer and closer. For other systems these rates of change, in a human scale, are much too slow, but we still believe that if we wait long enough they will get as near to an equilibrium state as we wish. On the other hand there are systems, such as the systems treated by Mechanics, which we may prefer to believe that they do not follow this systematic trend, in the sense that there seems to be no singular state to which the system would be finally attracted, intead, the system would cyclically recur always to the same states of a given class.

In order to formulate a theory of the behaviour of physical objects, we may thus adopt two ideological positions:

1. either the objects of physics can be separated into two distinct classes, one (a) for which no spontaneous cycle is possible, and other (b) for which spontaneous cycles are a necessity;

2. or this separation is not possible, every physical object belonging to class (a) above.

In the second case, on empirical evidence, we would say that the differences are only a matter of rates, and that sooner or later any isolated object will reach a final state of equilibrium. From this ideological point of view the theory of the evolution of isolated systems should be universal, different systems being characterized only by their rates of approach to equilibrium. This theory would be somewhat similar to Thermodynamics, and in this case Mechanics would be a mere idealization adequate only for relatively short periods of time, even though these times on a human scale may be very long.

On the other hand, in the first case there would be an essential difference between cyclic and non cyclic behaviour, that is, an essential difference between mechanical and thermodynamic systems. In this case the two classes can be separated by the criterion of whether the following proposition is true or false:

**"Principle of Evolution"**: "Every spontaneous process is irreversible".

The meaning of this proposition has to be understood as follows:

1) "Every" means that there are no exceptions.
2) "Process", in contradistinction with "state", is a linguistic element referring, not to one instant, but to two distinct instants.
3) "Spontaneous" means without the participation of other elements not pertaining to the object, which thus must be sufficiently rich in order to work by itself.
4) "Irreversible" means that if the process AB is true, then the process BA is false.

The Principle of Evolution is, obviously, a generalization of the usual proposition of the Second Law of Thermodynamics in which case "process" is explicity declared to be "process of heat transfer". However since in the proposition of the Principle of Evolution, the term "process" means "any process whatsoever", this proposition has the rank of an ideological principle, in the sense that it is always true. For instance if a given system is observed to recur to some specific condition, one would be forced to conclude that this recurrence is only apparent, implying that it would be forceful to search for some hidden variable of state without which the state of the object would not be completely specified, and when taken into account as a state variable it would be clear that the specific conditions in question are not really the same. To give an specific example, if an oscillating ideal frictionless pendulum resumes its initial position $x$ and velocity $v$ after a certain period T, one would argue, in order to save the ideological principle, that the state of this pendulum is not completely specified by $x$ and $v$ alone, but besides by another yet hidden variable $\zeta$ whose value does not repeat itself after the same interval T, which thus, would not be a true period. As a further example we may consider a common wrist watch moved by an electrical battery, without which the pointers would not move. After a period of twelve hours the pointers usually resume the same position and velocity as before. Nevertheless after this period the battery is run down, its state thus not being the same as it was twelve hours before. So the complete object, watch plus battery, capable of spontaneous change, never comes back to any previous condition.

## 3. THE IDEOLOGICAL CHARACTER OF PHYSICAL THEORY

Science being an interplay of empirical and theoretical ideas is always involved with propositions whose truth value depends on the implicit ideological plataform one chooses to stand, and not every scientific proposition can be proved true or false on empirical evidence alone. On etymological grounds we should prefer to use "veridic" and "unveridic" instead of "true" and "false" respectively.

For that reason we must recognize that the necessity or the impossibility of cycles in an isolated system are opposite and mutually contradictory ideological propositions, either one serving equally well as basis for the task for relating empirical observations by means of a set of ideas, linguistic propositions which constitutes a true theory.

In the apparently trivial case of heat phenomena, granted an inequivocal and unambiguous empirical criterion allowing one to assert that heat has flown spontaneously from A to B, one would automatically say that A is hotter than B in order to save the proposition that heat does not flow spontaneously from a colder to a hotter body. In this case if one would observe heat from A to B as well from B to A one would prefer to say that somehow the system (A + B) is not isolated, saving thus, the ideological proposition represented by the Second Law of Thermodynamics, which, if not quite defines, at least validates words such as "hotter", "colder", "flow", "before", "after", etc. This "law" cannot be inferred from any set of empirical observations alone, its content being purely ideological. From these considerations one may be inclined to say that thermodynamic way of reasoning and saying contains some ideological element.

On the other hand Mechanics being based either on reversible equations of motion, or on conservation principles, neither of which makes distinction between "before" and "after", corresponds to an ideology in which cycles are the rule, the concepts of "before" and "after" having no definite meaning whatsoever. For this reason Mechanics also has the character of an ideology, whose appropriate language does not contain linguistic elements, such as "before" and "after", which are meaningless in this language.

We may thus be inclined to conclude that Thermodynamics seems to correspond to an ideology whose language contains inequivocal linguistic elements such as "before" and "after". By the same token Mechanics would stem from an opposite ideology in whose language these same linguistic elements are meaningless. These two languages are thus mutually independent and in many instances contradictory, and any attempt of mutual confrontation will lead to unsolvable difficulties, since either of these two languages contains propositions which are meaningless in the other.

We should point out that Thermodynamics, understood as doctrine of heat phenomena, can be regarded as a branch of a more general theory, that is a world vision in which the Principle of Evolution is the basic ideological principle. This ideology stems from the belief that the contents of "before" and "after" are necessary and absolute, in the sense that no argument whatsoever should be sufficient to revert the order of two specific states A and B, for instance from "A is before B" to "B is before A", except for a trivial convention of interchanging these two words, in which case every relation, without exception, would have its order inverted. From this stand one should recognize that as an ideological principle the Principle of Evolution is applicable to any universe whatsoever, not only to those universes involving Joulean systems, understood as systems for which the effects of heat and work are equivalent, as discussed below.

## 4. JOULEAN SYSTEMS AND THE FIRST LAW OF THERMODYNAMICS

Many physical objects, for instance all those investigated by Joule, such as a quantity of a liquid, a piece of metal, etc., are observed to have the empirical property that, starting, from a definite initial state, sooner or later the system will attain a unique and well defined state or equilibrium, which depends only on the amount of energy exchanged with other systems, and not on the particular and specific ways by which this energy is interchanged. In this way, for instance, we may measure the quantity of thermal energy, heat, supplied to a Joulean system by comparison with that amount of work which would produce the same effect.

As a matter of fact as well as a conceptual matter, the concept of energy only makes sense on basis of Joule experiments and its conceptual extrapolation to every situation. Hence the historical importance of the experiments of Joule, and also the reason why the concept of energy is relatively new in Physics.

Empirical observations allow one to formulate the so called First Law of Thermodynamics: "The final state of a universe constituted by heat reservoirs, mechanisms of any sort and some joulean systems, for short the state of a thermodynamic universe, depends only on its internal energy". To avoid confusion we shall refer to this enunciation of the First Law of Thermodynamics by the name of "Joulean Principle".

We should notice that despite the frequent confusion in many textbooks on Thermodynamics, the Principle of Conservation of Energy is not sufficient as a First Law of Thermodynamics. Energy conservation is valid for any physical universe whatsoever, Joulean or not, for instance it should be valid for organized systems such as living beings. Nevertheless, the equivalence of heat and work seems to be a peculiarity of a few systems, Joulean systems. Living systems are clearly non-Joulean since, for instance, the effect of a comfortable warm shower is not the same as the effect of a shorter, but energetically equivalent, peeling hot shower, or in the extreme of an energetically equivalent, but lethal, electrical shock through the same shower device.

The conservation of energy is an ideological principle which means that we choose as stand an ideological plataform such that the following proposition is always unquestionably true:

"Energy Principle": The total amount of energy of an isolated system cannot change".

This means that to adopt this ideological plataform, is equivalent to assume the commitment by which in any situation whatsoever we shall always invent new forms of energy, in a way as to save the Energy Principle.

Bearing on mind the distinction between the Energy Principle and the Joulean Principle, we may speculate if whether or not every physical system is a Joulean system, that is whether or not every physical universe, if we wait "long enough", will decay to a unique state which depends only on its internal energy. Obviously limited human observation is insufficient as a criterion for decision on this question. Henceforth, as in the case of the Principle of Evolution or the Second Law of Thermodynamics, all we can do is to adopt either of two conflicting ideological plataforms:

1. either the objects of physics can be separated into two distinct classes, one (i) of Joulean systems, in the sense defined above, and other (ii) of non-Joulean systems:

2. or this separation is not possible; every physical object being either (i) a Joulean system, or (ii) a non-Joulean system.

The question of whether or not every physical object is a Joulean system cannot be decided by experiment. For those isolated systems for which one does not observe a clear and definite final state of equilibrium, one may, if one wishes, always argue that we have not waited long enough, the rates being too slow, but if we wait long enough we shall observe a clear and well defined final state of equilibrium. Nevertheless one may argue in favour of the opposite ideological stand, and say that the approach to a final state of equilibrium is only apparent, since the criteria we choose as defining a state are much too coarse, and if we refine our observations we shall observe that what we call a final state of equilibrium is really a myriad of substates whose fine distinction does not show up in coarse observations.

Here again the matter is a question of ideology. One must from the begining, choose a plataform, a way of thinking, which defines one's language. This can be accomplished by the commitment contained in the adoption of an ideological principle.

For instance if one wishes to regard inert as well as living objects on the same standing, one may assume as an ideological principle 2(i) that "every physical object is a Joulean system", which implies that every universe will attain a final state of equilibrium which depends solely on its internal energy. The meaning of this proposition is that, not only the energy principle is applicable to every system, but besides, the First Law of Thermodynamics as enunciated in this paper, is also universally valid, thus acquiring the rank of an ideological principle, the Joulean Principle.

On the other hand if one wishes, according to alternative 2(ii) to maintain that no separation is possible, but instead that every physical object is a non-Joulean system, one cannot assume the ideological Joulean Principle. In this case would we remain without an alternate ideological principle, or must we adopt an ideological alternative? The reason for this doubt is that, as discussed above, one may always argue that strictly speaking there are no objects such as Joulean systems, the concept, as well as the First Law of Thermodynamics, being a mere approximation, in the sense that the state variables used by Thermodynamics should correspond only to an approximate description, in which many true state variables are left out of consideration. In this case if these neglected variables were taken into account in the definition of state, one should see that the "final" state is not really unique and well defined. What, from the point of view of Thermodynamics, we call "final state of equilibrium" would truly be a myriad of states differring by the values of other non-thermodynamic variables which should be taken into account in some better approximation. This point of view, according to which no physical system is Joulean, is the opposite ideological stand by which we believe that every physical system is Joulean, as discussed before.

Finally we may prefer the choice of the first alternative according to which the objects of physics can be separated into two distinct classes, accordingly to the criterion of whether they are Joulean systems or not. In this case one would have two theories, two languages, each one appropriate to each class of objects, and no translation should be possible from one language to another.

## 5. A METHODOLOGICAL EXERCISE

As a methodological exercise we want to discuss a well defined and coherent point of view. We choose as an example the stand by which both the Joulean and the Evolution principles are adopted as preferred ideological plataform. In this case, as a consequence, we have at our disposal a language in which words such as "before", "after", "diffusion", "evolution", "process", "flow", etc., are meaningful on basis of the Evolution Principle which establishes the basic and absolute difference between "before" and "after". The difference can be traced back to the concept of "order". Order is an intellectual concept and a linguistic element referring to a generic abstract relation between any pair of entities A, B, C . . . which must fulfil two basic requirements, viz. it must be asymmetrical and transitive, and thus we may conclude that the relation is also non-reflexive.

Obviously these requirements cannot be satisfied if cycles are allowed as a further possible relation among the same entities A, B, C . . . Therefore the impossibility of cycles is necessary for the establishment of some relation of order. In the case in which the entities A, B, C . . . are the states of a universe regarded from the point of view of the Principle of Evolution, we may say that both the state variables as well as any state function or property of this universe is ordered. The question remains whether this order has a simple character such as the order of the points on a line or if, depending on the complexity of the system, this order cannot, as a rule, be cardinalized, in which case we must resort to some ordinal description beyond the elementary order relation among the cardinal numbers. In this case a general, and yet undiscovered, non-cardinal variable which we may call "age" of the isolated system would be an ordinal measure of the stage of evolution of this system. However, since we are adopting an ideological plataform according to which every system is Joulean, soon or later the behaviour of this universe will be closer and closer to the common behaviour of Joulean systems, i.e. the systems will approach a final state of equilibrium in such a way that the nature of the energies exchanged among the different parts of the system is irrelevant in this Joulean stage, and so the final state is determined solely by the total energy of this universe. In this case the closer the system gets to this state of equilibrium the better becomes the approximate description afforded by common classical thermodynamics, and thus the concept of entropy, for instance, becomes more and more apt to describe the steady evolution of the system. In this way the ordinal evolution variable "age" will little by little merge into a cardinal variable, entropy.

Accordingly to this ideological point of view, a universal theory, a single world vision, is sufficient to describe the behaviour of every physical object. Any object at the beginning, short after the constraints are released, will display a more or less organized behaviour whose description has to be based on a general ordinal state variable "age". Nevertheless as time goes by, the behaviour of the system becomes more and more chaotic, and a cardinal entropy becomes an acceptable state variable as a measure of the stage of evolution, or age, of the system.

From this point of view both Mechanics as well as Thermodynamics are approximate descriptions, not true theories, the first adequate as an approximate description of "fresh" universes, and the latter adequate to "worn out" systems, or in a better way of saying, adequate to the Joulean stage of the universe.

## 6. CONCLUSIONS

Our analysis reveals the ideological character of physical theories. Empirical observation alone is not sufficient to establish a unique basis for theoretical physics. An ideological element, constituted by commitments to certain principles which determine the language, is necessarily present in every type of discourse relative to the observation of physical objects. Different ideologies imply different, non equivalent, mutually untranslable languages. A methodological exercise shows that it is possible to choose an ideological plataform according to which any isolated system (i) soon or later reaches a final state of equilibrium determined by its total energy alone, (ii) the approach being steady and unilateral, a true evolution process in which no previous state is reassumed. The stage of this evolution process should be describable by some, yet unusual, ordinal variable which in the later Joulean stages of evolution can be approximated by ordinary cardinal entropy. From this point of view Mechanics is not more than an approximate description adequate only for the beginning stage of evolution, whereas Thermodynamics should be an adequate approximated description for the latter stages.


### REFERENCES

1. "Webster's Third New International Dictionary", several editions, G &G. Merriam Co., Chicago, London, etc.